23rd European VLBI Group for Geodesy and Astrometry Working Meeting, 14-19 May 2017, Goteborg, Sweden

Twin Telescope Tests:

Assessing Station Oriented Systematic Errors

Christopher S. Jacobs,

Jet Propulsion Laboratory, California Institute of Technology

C. Garcia-Miro, S. Horiuchi

Overview:

- VLBI astro-geo goals are now +- 1mm

- XKa celestial frame is dominated by systematic errors, not random errors (precision).
  Need to identify sources of systematics including antenna structure and instrumentation

- Test if we can achieve +-1mm even over short baselines with highly cancelling errors.

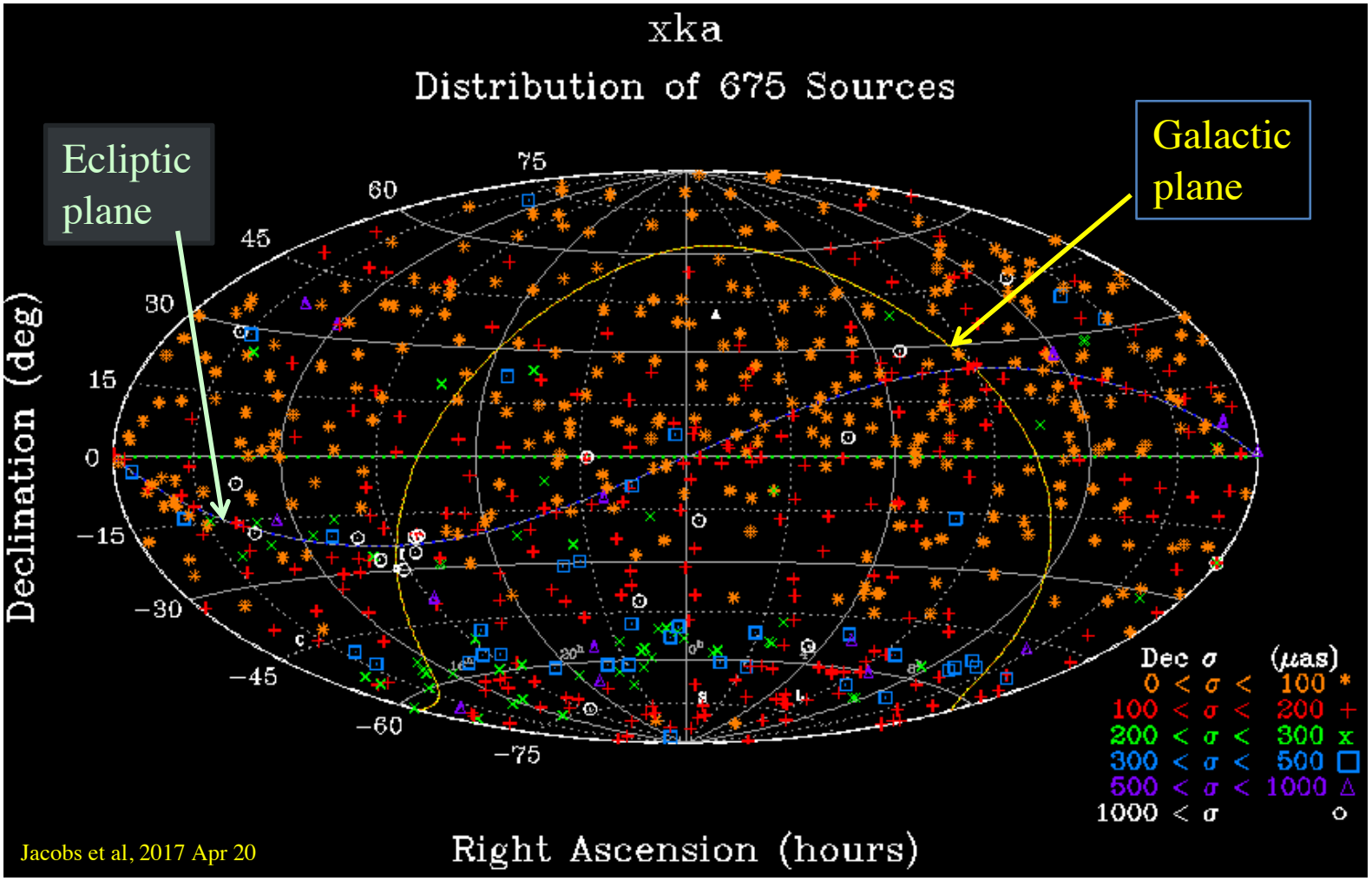
- Use NASA Deep Space Net beam-waveguide antennas
  At least two per complex, 200 to 300 meter baselines
  shared clocks, atmospheres, mechanical design.

- Historically we have assumed that these station are on same bedrock
  and have zero relative velocity to better than +-1mm per decade

- Goldstone tests circa 2005 suggested this was true

- Recent tests at Robledo, Spain challenge the assumption

Ka (32 GHz, 9mm) Combined NASA/ESA Network



- Strengths:
  - Uniform spatial density
  - less structure than S/X (3.6cm)
  - precision < 100 μas
  - needed only 60K observations vs. SX's 12 million!

- Weaknesses:
  - Poor near Galactic center due to inter-stellar media scattering
  - South weak due to limited time on ESA's Argentina station
  - Limited Argentina-California data makes vulnerable to δ zonals
  - Limited Argentina-Australia weakens δ from -45 to -60 deg

Ka-band combined NASA/ESA Deep Space Net

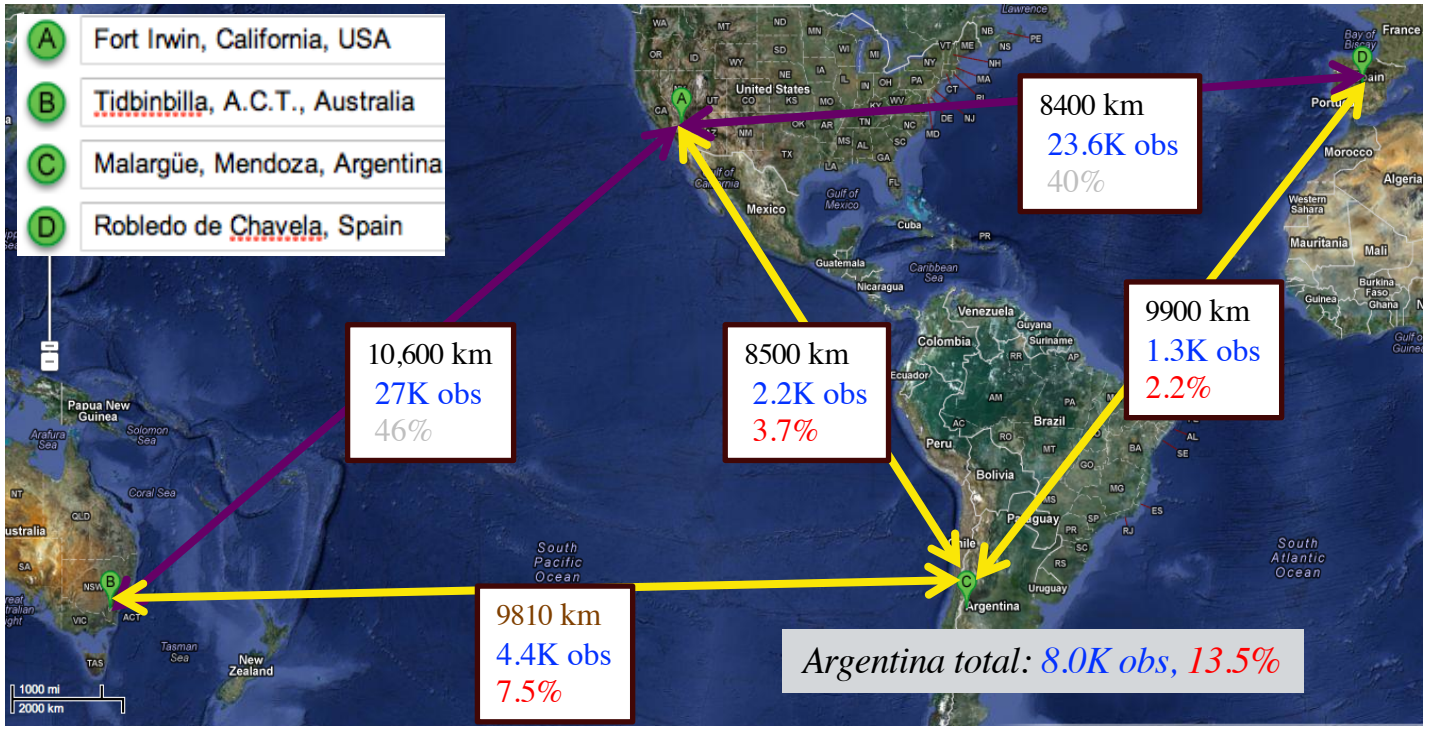
ESA Argentina to NASA-California under-observed by order of magnitude!

Baseline percentages

- Argentina is part of 3/5 baselines or 60% but only 13% of obs
- Aust- Argentina 7.5%
- Spain-Argentina 2.2%
- Calif- Argentina 3.7%

This baseline is under-observed by a factor of ~ 12.

More time on ESA's Argentina station would have a huge, immediate impact!!



Maps credit: Google maps

ESA's Argentina 35-meter antenna **adds 3 baselines** to DSN's 2 baselines

- Full sky coverage by accessing south polar cap
- near perpendicular mid-latitude baselines: CA to Aust./Argentina

Three VLBI bands compare to better than 200 μas RMS
Gaia DR-1 precision ~ 500 μas. DR-2 vs. VLBI may reveal zonals

Zonal Errors

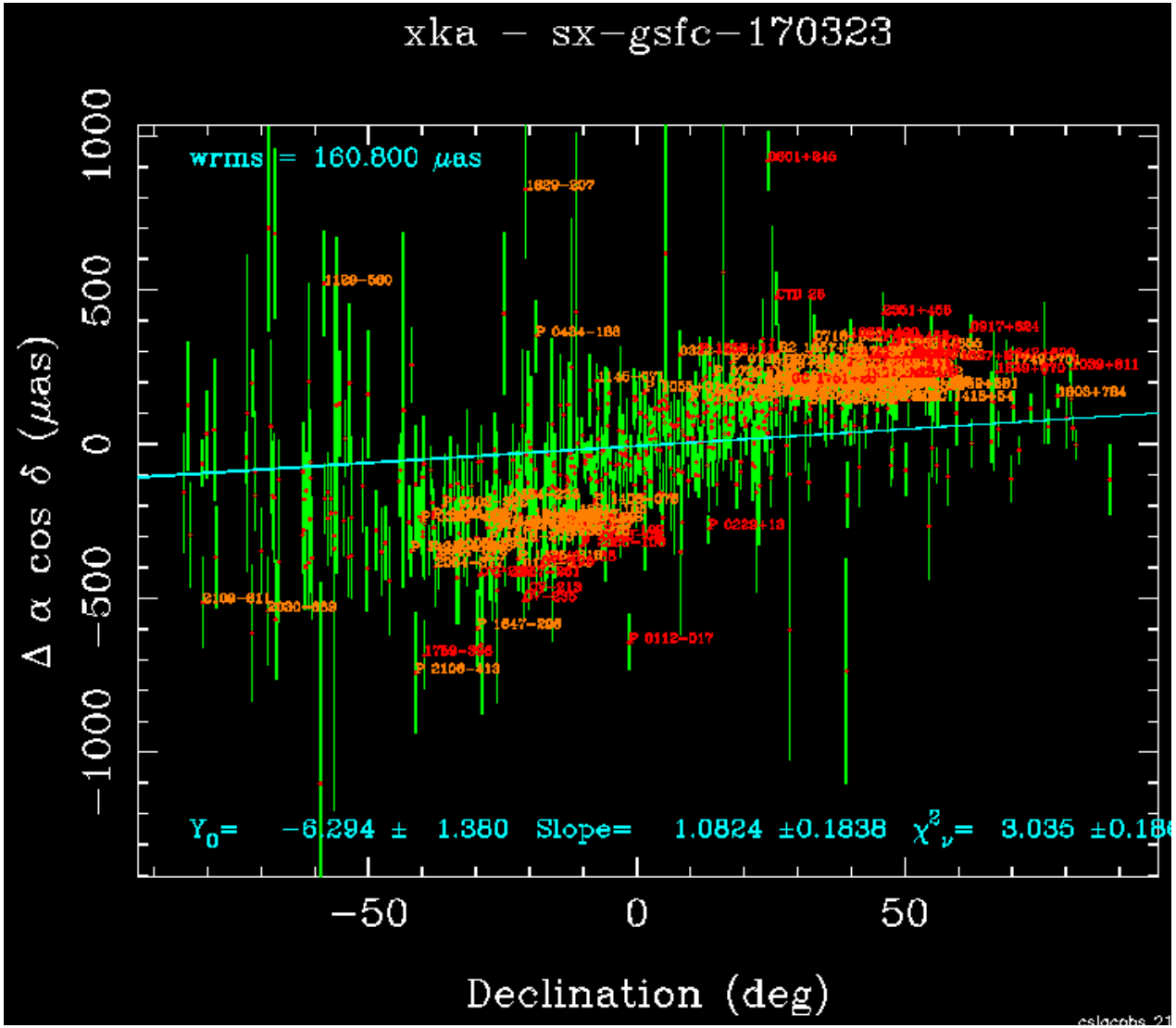
- ΔRA vs. Dec:
  ~300 μas in south, 200 μas in north

- Need 2 baselines to get 2 angles:
  California-Canberra: 24K obs
  California-Argentina: 2K obs

-> Need more California-Argentina data to overcome this 12 to 1 distortion in sampling geometry. ESA's Malargüe is key.

- Usuda, Japan 54-m XKa (2019) would improve North-South sampling geometry and thus control declination zonal differences.

XKa vs. SX: Zonal errors

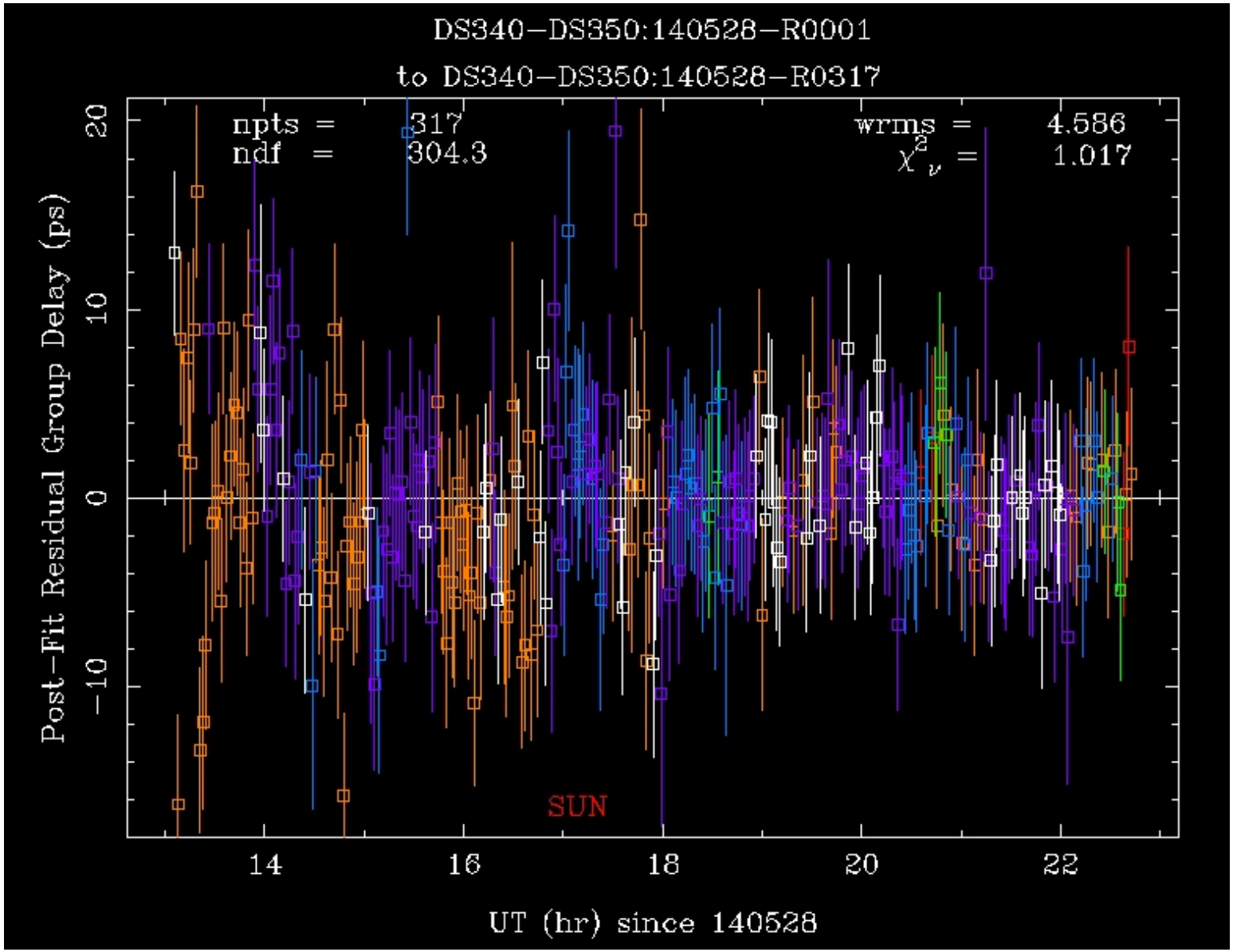


Credit: SX astrometry, D. Gordon

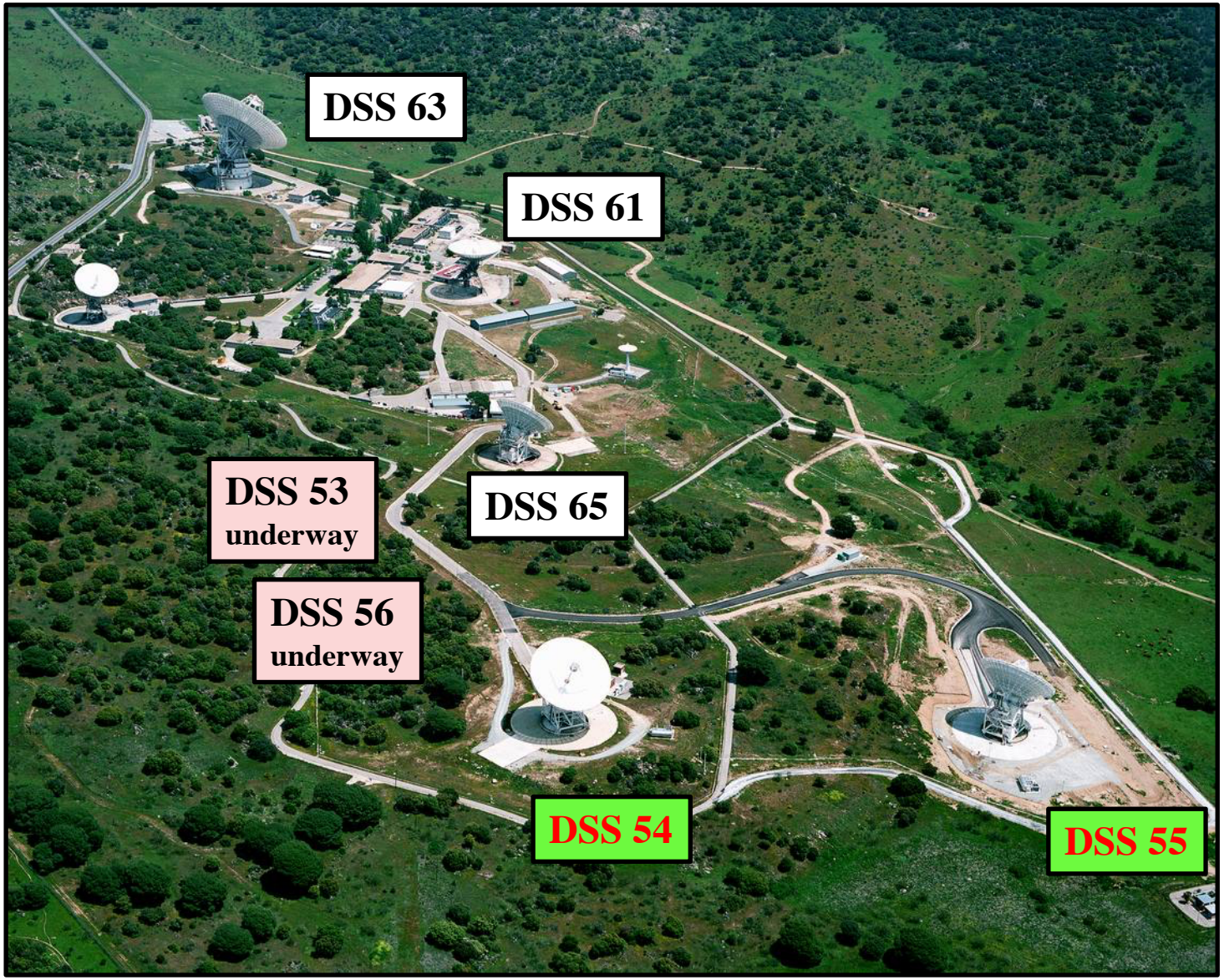
NASA Deep Space Network: Robledo, Spain

Year	Mo	Day	Stations	Nobs	wRMS	
2014	05	28	34-35	317	4.6 psec	Canberra
2014	07	12	34-35	132	6.3	
2014	07	19	34-35	153	2.7	
2014	07	25	34-35	261	11.2	
2016	06	18	34-35	178	4.4	
2016	07	14	34-36	111	3.7	
2016	07	17	34-36	125	11.4	
2016	09	23	34-36	188	3.3	
2015	12	05	54-55	119	5.2	Madrid
2016	01	31	54-55	132	5.4	
2016	05	07	54-55	167	4.1	
2016	07	09	54-55	93	5.2	
2017	01	03	54-55	188	3.3	

Group Delay scatter: DSS34 to DSS35



NASA Deep Space Network: Robledo, Spain



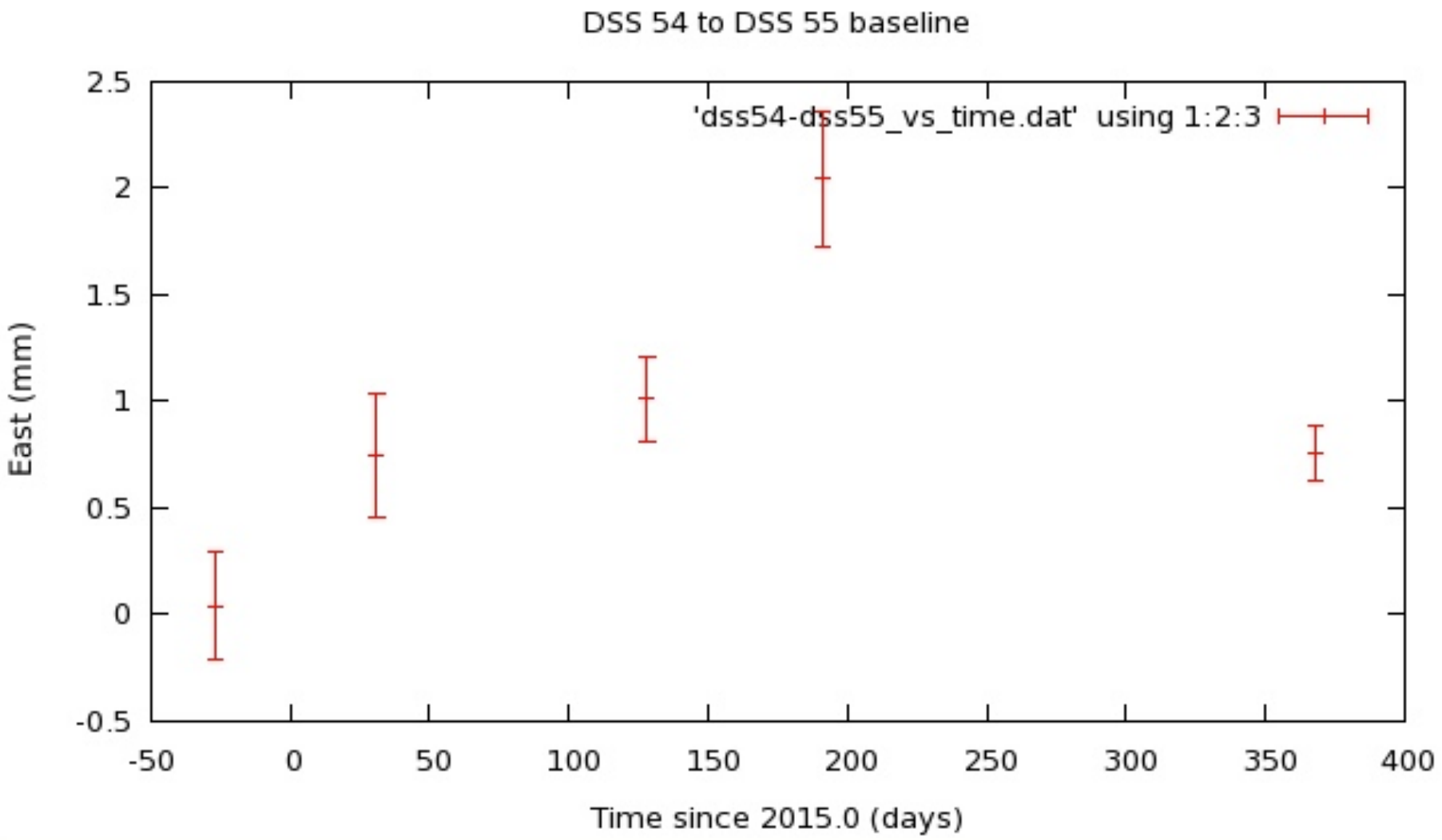
DSS 54, 55:

34-meter, XKa
Beam-waveguides
"identical" design

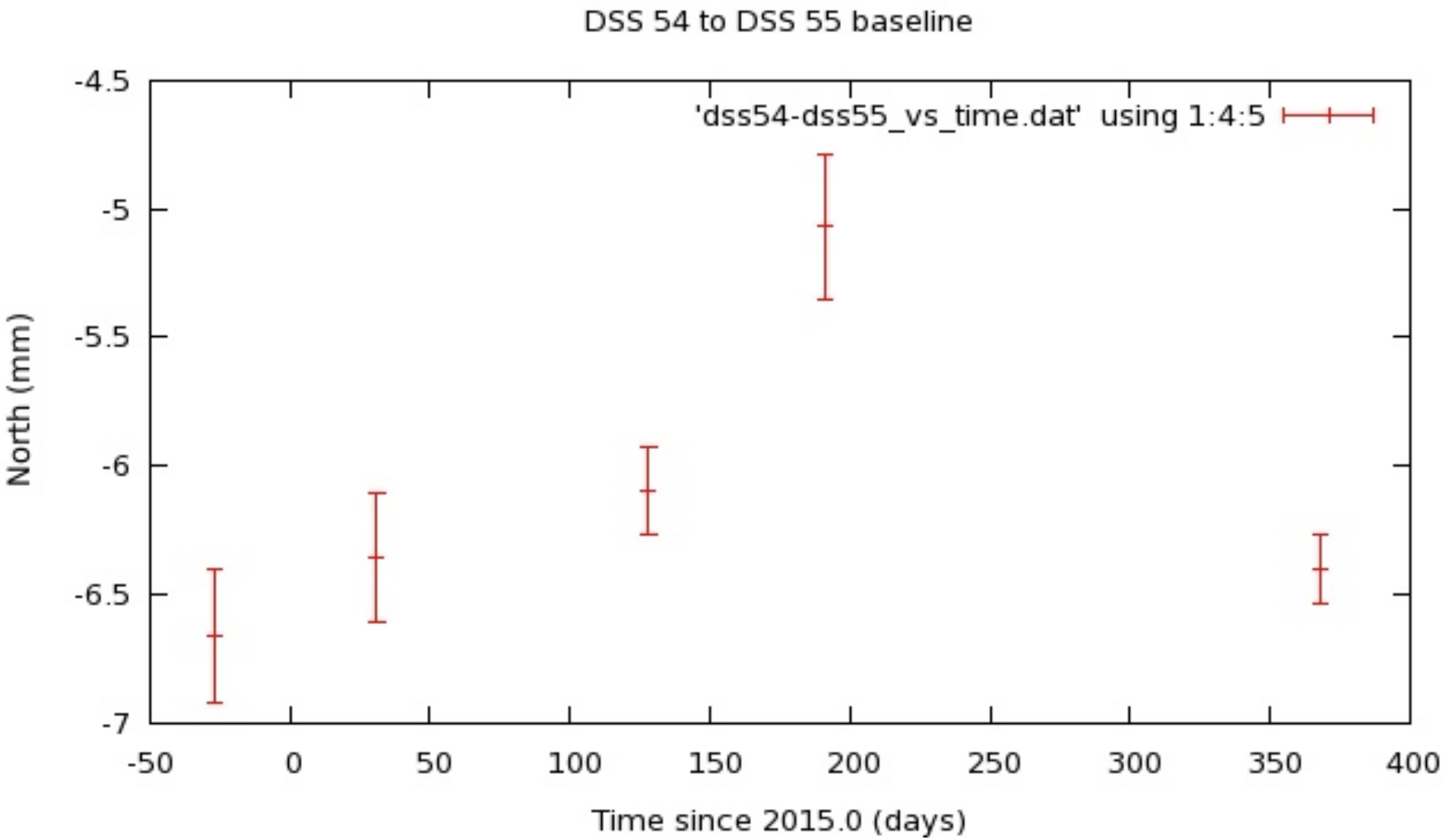
<u>Common:</u>
Mechanical design
Clock
approx. troposphere
approx. geophysics

<u>Different:</u>
Last few 100 m
of cabling.
Local geophysics?
Local hydrology?
Out of spec
instrumentation?

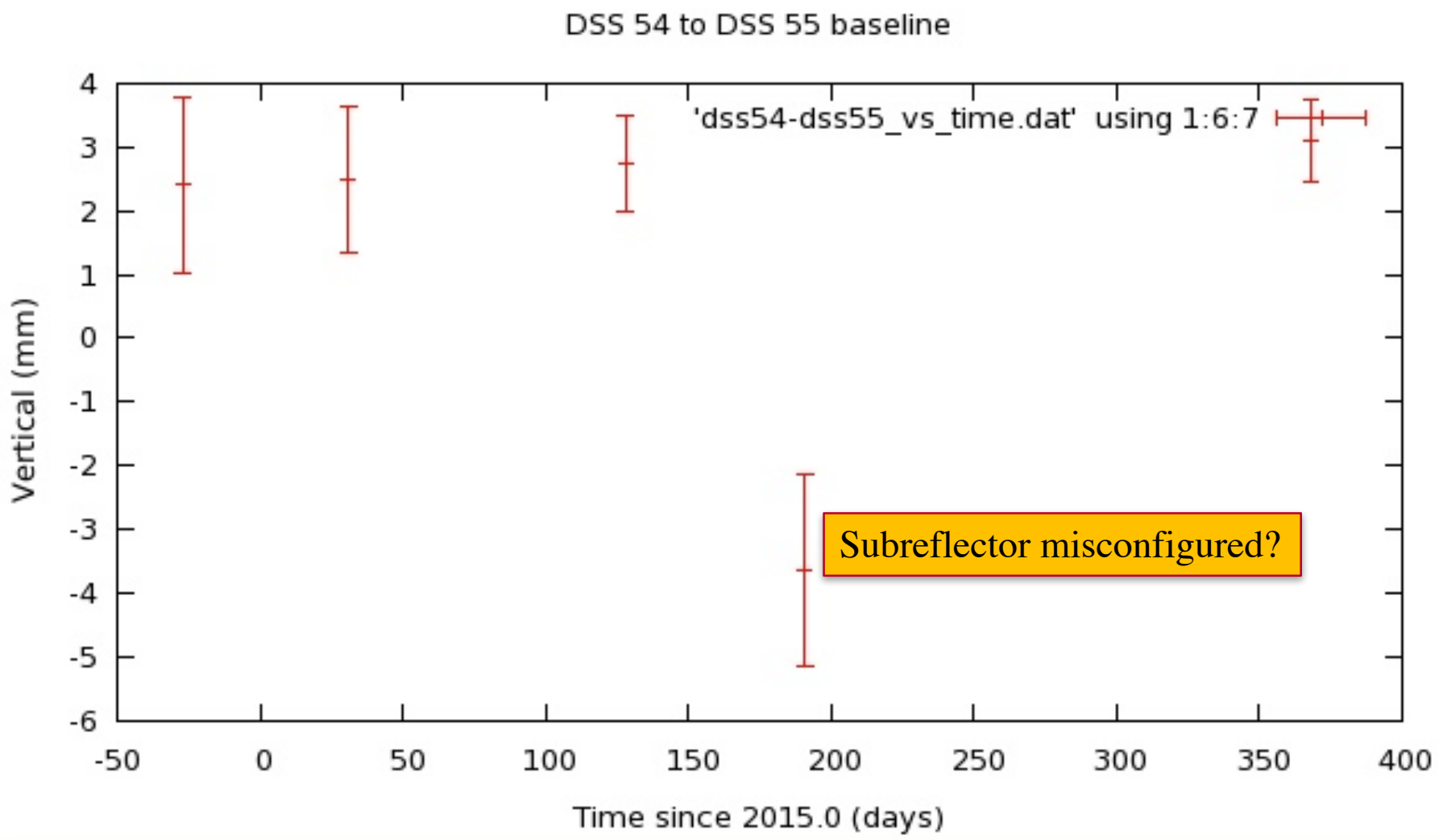
DSS 54 to DSS 55: East Component



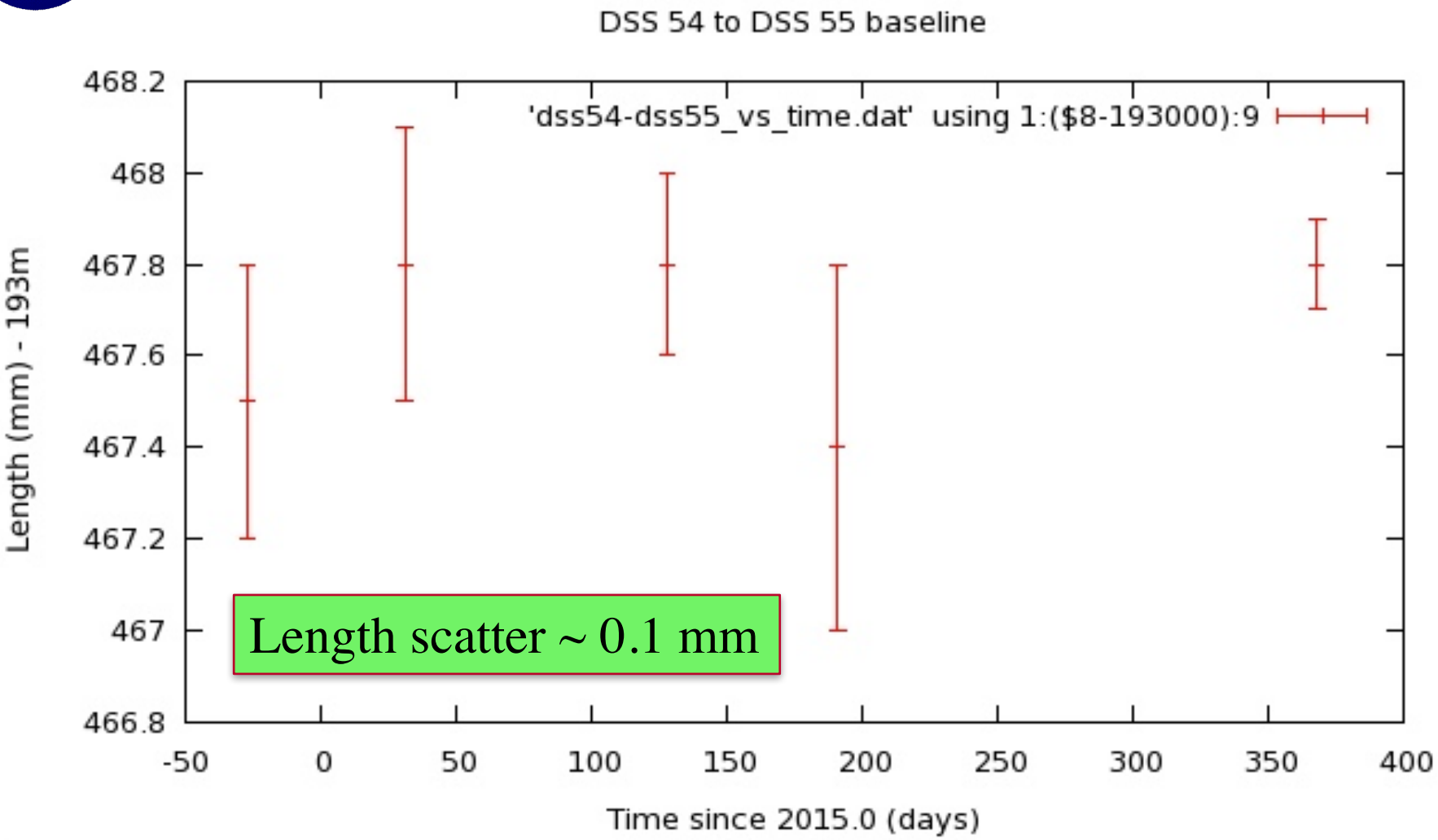
DSS 54 to DSS 55: North Component



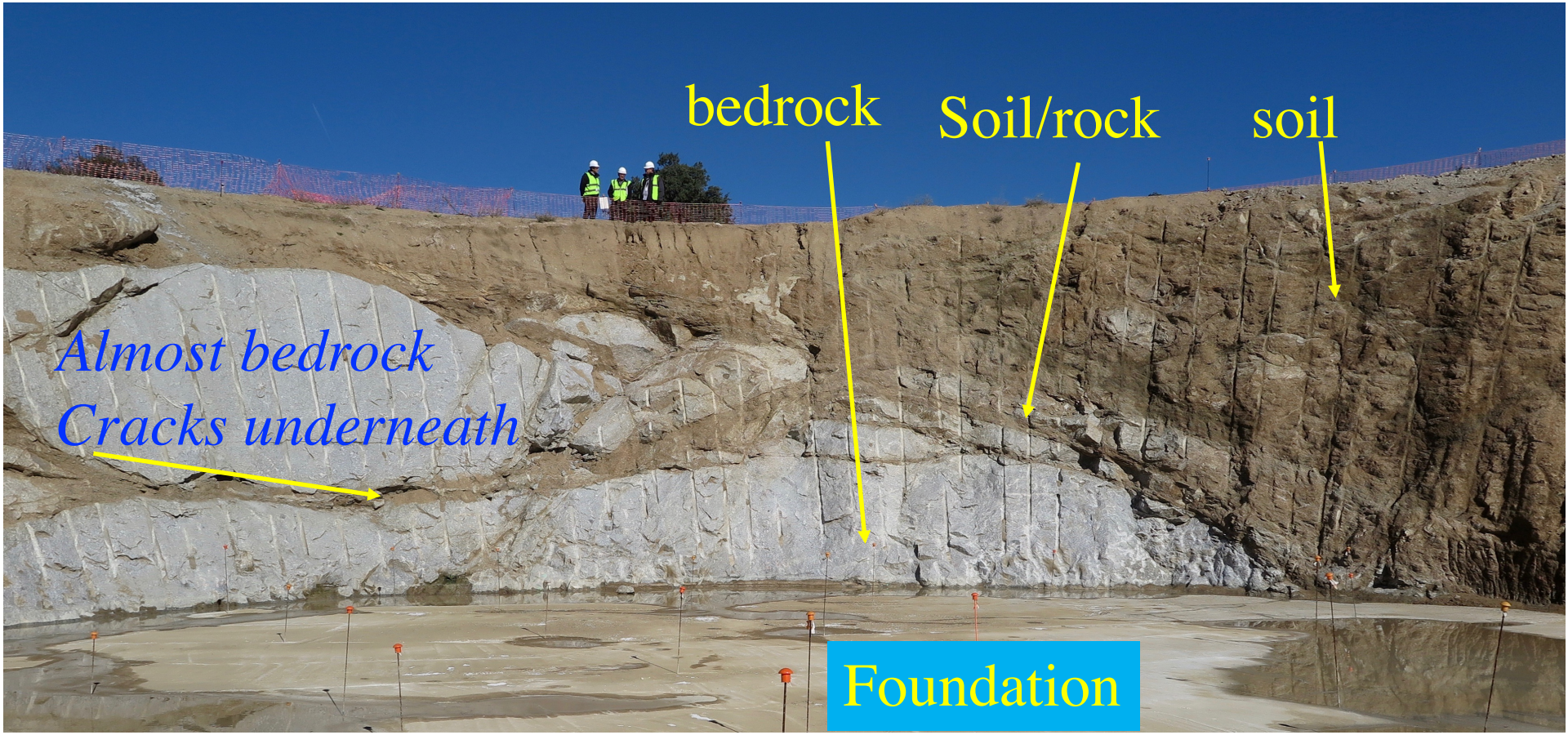
DSS 54 to DSS 55: Vertical Component



DSS 54 to DSS 55: Length Component

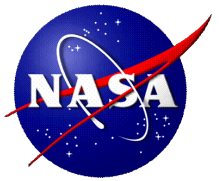


Foundation of DSS 56 under construction



Can the foundation slide horizontally?
Are there local micro-faults? Very local ground water changes?

Summary: Twin Telescope Tests



- **Goal:** to isolate telescope to telescope variations by measuring in an environment where most error sources common mode away.

- **Results:**
  A series of short baseline connected element interferometry passes
  8 passes at DSN Canberra
  5 passes at DSN Madrid
  1 to 4 mm delay scatter

- Canberra baselines are generally stable at near the +-1 mm level

- Madrid baselines show several mm variations from pass to pass. Cause of scatter is unknown.

- Work is ongoing. Seasonal effects? Outliers? Need bigger sample.